ASTEROID SPIN DATA: NO EVIDENCE OF RUBBLE PILE STRUCTURES.

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Introduction: A comparison of the spin periods of asteroids with the limit spin at which a rubble pile structure will fly apart from centrifugal forces has been used in the past to conclude that many, if not most asteroids have a rubble-pile structure with no cohesive strength. The simplest analysis is based on the spin at which a loose particle would fly off of the equator of a spherical body [1]. A more elaborate analysis is for an ellipsoidal body consisting of a material with a Mohr-Coulomb or a Drucker-Prager model, which is appropriate for a granular material without cohesion [2], [3]. A new analysis of the limit spins for an ellipsoidal body with strength dispels that rubble-pile conclusion.

Material Strength of Rocks: A quick web search will give that laboratory rocks typically have tensile strength of a few tens of MPa. However, a consequence of their crack and flaw structure is that the strength is strongly size dependent, so those values do not govern asteroid-sized rocks. For example Housen and Holsapple [4] measure a reduction in the tensile strength of Georgia Keystone granite with the power of -0.25 of the linear dimension (Fig. 1) over a range of about a decade in size scale. That is also predicted if there is a Weibull distribution of crack or flaw sizes with the number per unit volume with a length greater than ϕ of the form $n = kl^{-\phi/2}$ with the Weibull exponent $\phi = 12$. Measurements of the actual crack lengths in those granite specimens do show that distribution exponent for the large cracks sizes that govern static strength (Fig. 2).

Further, there is evidence that the same distribution carries to very large sizes. Fig. 3 shows measured surface fault sizes up to a scale of almost 10 km, and they still have the power-law form, all asymptotic to a power-law curve with a Weibull exponent of *6*.

Spinning Ellipsoidal Bodies: A recent analysis of the stress states and limit spins in ellipsoidal bodies with self-gravity and with strength has extended the analysis for cohesionless bodies to those with cohesive strength. A Mohr-Coulomb model was used again, but the cohesion term is not zero. The results allow one to determine a limit spin at which the body would fail as a function of the shape, mass density and spin. These results are for a given constant cohesion and were presented before [5]. However, in view of the new observations about the decrease in strength with size, a size dependent strength is more appropriate. The results of that analysis are shown in Fig. 5. Also, on that same plot are the data points for a number of asteroids including the so-called "fast spinners" found in the last few years. In addition, a number of main-belt asteroids have just been discovered in the range of about a km diameter that are also above the old "spin limit' for rubble-pile bodies. (These are not shown below, they will be added) Taken together, there is now compelling evidence that the asteroids are limited by a strength-determined spin, not a rubble-pile-determined spin, so the spin data can no longer be invoked to deduce that many asteroids are rubble-piles.

References:

[1] Harris, A. W. (1996) Proc. Lunar Planet. Conf. 27th, 493-494.
[2] Holsapple, K. A. (2001) *Icarus 154*, 432-448.
[3] Holsapple, K. A. (2004) *Icarus 172* 272-303.
[4] Housen, K. R. and K. A. Holsapple (1999) *Icarus 142* 21-33.
[5] Holsapple K. A. (2003) Proc. Lunar Planet. Conf. 34th, Abstract 1792.

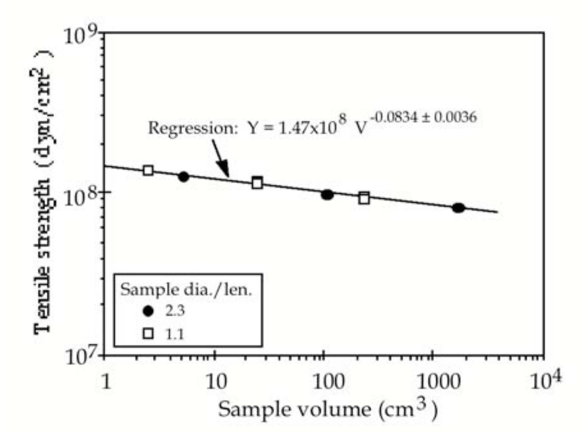

Figure 1. The tensile strength of granite samples as a function of their volume. From [4].

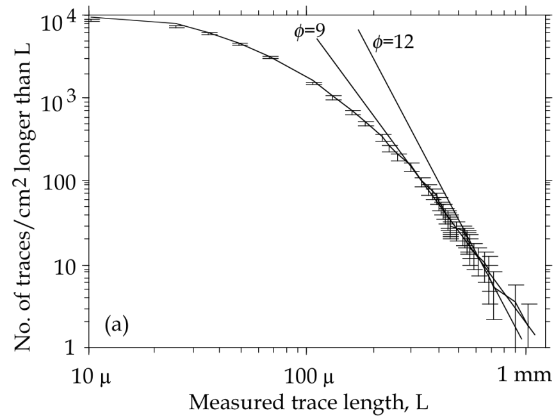

Figure 2. The measured surface trace length distribution of a small granite sample.

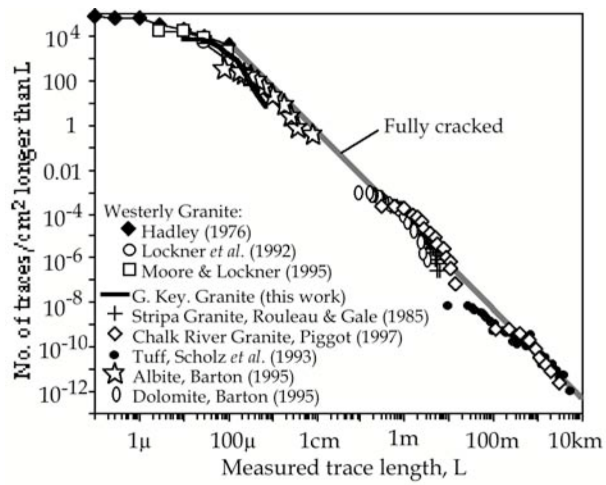

Figure 3. Surface fault sizes in terrestrial rocks to a scale of 10km.

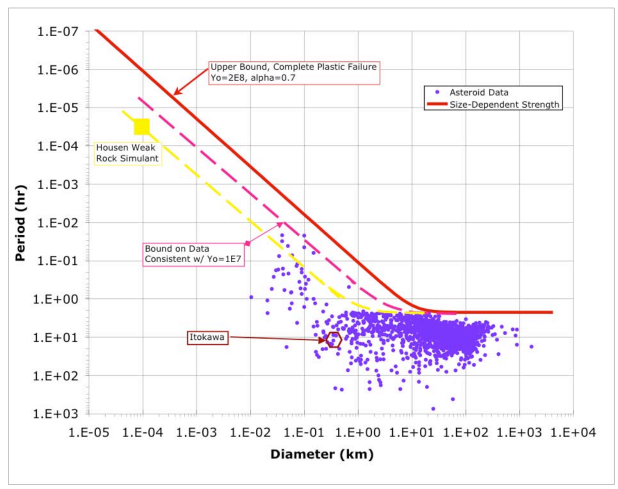

Figure 4. Asteroid spins compared to limits for a cohesive rocks of large sizes.